Division of Agricultural Sciences
UNIVERSITY OF CALIFORNIA

TURKEY BREEDING RESEARCH IN THE WESTERN UNITED STATES

V. S. ASMUNDSON
F. X. OGASAWARA
R. E. MORENG
J. A. HARPER
W. A. BECKER
D. C. HUTTO

A WESTERN REGIONAL RESEARCH PUBLICATION

CALIFORNIA AGRICULTURAL EXPERIMENT STATION

BULLETIN 830

The Western Regional Turkey Breeding Project W-7 was approved in July 1947, and the cooperating Experiment Stations throughout most of the period 1947 to 1964 included California, Colorado, Oregon, Utah, Washington, and Wyoming, with the Utah Experiment Station withdrawing from the project in 1962. The Technical Committee membership during the existence of the project was as follows:

State or governmental agency	Committee member	Period served
California	V. S. Asmundson	1947–1962
	F. X. Ogasawara	1963–1964
Colorado	H. S. Wilgus	1947–1949
	E. G. Buss	1950–1955
	R. E. Moreng	1956–1964
Oregon	J. E. Parker	1947–1949
	J. A. Harper	1950–1964
Utah	C. I. Draper	1947–1949
	A. B. Stephenson	1950–1953
	J. D. Carson	1954–1961
Washington	I. L. Kosin	1947–1959
	W. A. Becker	1960–1964
Wyoming	L. Morris	1947–1949
	G. T. Davis	1950–1956
	D. C. Hutto	1957–1964
USDA	S. Work	1947
	R. B. Nestler	1952–1955
	W. E. Shaklee	1956–1962
	E. C. Miller	1963–1964
USDA Coordinators	D. C. Warren	1947–1955
	S. C. King	1956–1958
	J. R. Carson	1959–1960
	C. W. Hess	1961–1964
Administrative Advisors	S. S. Wheeler	1953–1955
	D. S. Carver	1956
	L. W. Rasmussen	1957–1958
	M. M. Rosenberg	1959–1964
USDA, PRB, AHRD	S. J. Marsden	1957–1964

The opportunity for Committee members to meet provided a nucleus for germination of ideas and stimulation for research on a cooperative basis. Knowledge so obtained has now become part of turkey production. Regional research funds, along with state funds, have been returned many times over in terms of decreased losses and added profits in the turkey industry.

Under procedure for cooperative publications, this regional report becomes in effect an identical publication of each of the cooperating agencies, and is mailed under the frank and indicia of each.

This bulletin summarizes the research findings of Western Regional Turkey Breeding Project W-7 for the years 1947 to 1964. The research was concerned with the broad areas of growth, fertility, egg production and hatchability, and their relationship to genetic and environmental factors.

APRIL, 1967

The Authors:

California

V. S. Asmundson, Department of Poultry Husbandry, University of California, Davis.

F. X. Ogasawara, Department of Poultry Husbandry, University of California, Davis.

Colorado

R. E. Moreng, Professor and Head of the Department of Poultry Science, Colorado State University.

Oregon

J. A. Harper, Professor of Poultry Science, Department of Poultry Science, Oregon State University.

Washington

W. A. Becker, Professor of Poultry Science, Department of Animal Sciences, Washington State University.

Wyoming

D. C. Hutto, Instructor, Division of Animal Science, University of Wyoming.

TURKEY BREEDING RESEARCH IN THE WESTERN UNITED STATES[1]

EGG PRODUCTION RESEARCH

Breeding Systems

In studies involving eight strains of Broad Breasted Bronze (BBB) turkeys the reproductive efficiency of strain crosses was generally greater than that of pure strains, and egg production for the strain crosses was 11 to 40 per cent higher. In other experiments, inbred lines developed over a 10-year period and having coefficients above 75 per cent showed a decrease in reproductive traits as compared with non-inbred lines. Inbred turkey females laid 25 per cent fewer eggs than did non-inbred females, while top-crossed females laid 18 per cent more eggs. Survival within inbred lines was low, and the lines were difficult to maintain.

Trapnest egg production for 12 weeks only was highly correlated (+ 0.81) to total season production of 22 weeks. This suggests that a short period is adequate for sampling egg production to provide data for determination of matings within a generation. Further experiments on selection of BBB turkeys showed that age at sexual maturity was decreased, and the number of eggs increased, in an early-maturing line as compared to a late-maturing line. Females of the early-maturing line started to lay 2 to 14 days earlier, paused less frequently, and laid an average of 59.6 eggs per female; the average was 34.6 eggs for the late-maturing line. Information obtained suggests that a turkey-breeding program combining selection for early sexual maturity, partial reproduction records, and artificial insemination to overcome effect of prior matings, should shorten the time between generations and increase the rate of genetic improvement.

[1] Submitted for publication January 25, 1966.

Lighting Systems

The light environment which turkeys are exposed to has a profound effect upon their age at sexual maturity, and on the number of eggs produced. Studies in this regional project therefore explored lighting as one of the factors related to artificial control of egg production cycles.

Season

Egg production begins about March 1 (plus or minus 2 weeks for various latitudes in the western states), and physical maturity of turkeys is reached in summer or fall. Short winter days retard sexual maturity, but increasing day-lengths stimulate the fowl's optic nerve, causing an interaction between the pituitary and gonad which produces a normal reproductive state. Artificial light may be used to supplement or replace natural light in order to influence reproduction.

Age

The effect of time of lighting, and of the length of the exposure to autumn's shortening days, was observed in three lines of BBB June-hatched turkeys. With a 14-hour light-day provided at 169 days of age, the median age at sexual maturity for females was 218 days for an early maturing-line and a control line; for a late-maturing line it was 254 days. The time of response (egg-laying or production of semen) to lights was 44 days for the early-maturing and control lines, and 89 days for the late-maturing line. When exposure to the 14-hour day (long day) started at 197 days, all lines varied from 25 to 31 days to first egg. When lights to increase light-day-length were started on all lines at 224 days,

age at sexual maturity was 245–246 days (with average time to first egg being 21 to 22 days). The experiment shows that sexual maturity in turkey females may be delayed by increasing day-length too soon in autumn without sufficient initial exposure to a short light-day. In another experiment (not described here) turkey females responding earliest to artificial light produced the most eggs. Females laying within 19 to 20 days following lighting laid an average of 64 eggs, while for each delay of 2 days in sexual maturity there was an average six eggs decrease in production. Females showing the most rapid response to light exhibited less tendency toward broody and non-broody pauses.

Strain

Genotype-environment interactions, observed in an experiment involving three lines of turkeys under artificial lighting, indicated that testing of strains for response to lighting programs might be appropriate.

Restriction of Light

A number of experiments were conducted to determine the cause of low egg production in summer and fall. Winter-hatched turkey females were kept on natural light after reaching 23 weeks of age, or were restricted to 9 hours of light daily for 3 weeks; after this treatment all groups received 17 hours of light daily. The hens which had had 2 or 3 weeks of light restriction laid considerably more eggs in successive months. It was therefore concluded that turkey females exposed to long light-days during growth were likely to be refractory (non-responsive) to light, and that a short day-length is required to precondition the pituitary gland to respond to a long light-day.

Later experiments demonstrated that turkey females preconditioned with 6 hours of light, followed by 10 hours exposure later, laid substantially more eggs after exposure to a long light-day (14 hours or more). A 4-week light-restriction period was as effective in terminating refractoriness as was 6 or 8 weeks.

Intensity of Light

Experiments over 4 years showed that red light, and uniform intensity levels of incandescent white light of 0.6, 1.2, 1.7, 2.5, 10.0 and 40.0 ft-c (foot candles) at bird height, were equally effective in stimulating egg production from December through May. There was some indication that the 40 ft-c level may have had an adverse effect on length of the laying period.

Turkey females exposed to a 16-hour light-day, with intensities of 2 or 4 ft-c, laid more than they had laid after a 5-minute exposure to 1500-watt bulbs. Females on a 13-hour light-day of 2.0 or 4.0 ft-c intensity laid at an intermediate rate (3 to 4 eggs a week).

October-hatched turkeys preconditioned for 8 weeks, beginning at 22 weeks of age by lowering light intensity to approximately 0.01 ft-c, had egg production equal to preconditioning with 8 hours light daily at 4.4 ft-c. Average egg production per female for the low-intensity light treatment was 97.6, and 97.1 for the high-intensity treatment; the average of 63 per cent during a 22-week season was equal to that normally obtained from spring-hatched turkeys over a similar period.

Sex

In several experiments it was shown that male turkeys do not exhibit a lack of response to long light-days, as do females. Preconditioning of winter-hatched turkey males by restricted light-day length is not necessary for semen production.

Duration of Light

An abrupt change in lighting of turkey females, from a 9.5 hour light-day for preconditioning to 13 or 15 hours, resulted in faster ovarian response than did 30-minute daily increments starting at 9.5 hours until a total of 15 hours was obtained. For the abrupt-light-treatment females, there was a significant improvement in egg production, a decreased time to laying of the first egg following light increase, and increased poult production.

A step-down light-preconditioning plan, involving gradual shortening of the daily photoperiod from 24 hours at 0 to 9 weeks

of age to a minimum of 14.5 hours natural light, was not effective. Possibly a shorter terminal step-down photoperiod would be more effective, if followed by an increased increment of daily light.

Drugs

Experiments with November-hatched turkey females showed that when diethylstilbestrol was injected at a rate of 10 milligrams per week for 4 weeks, or given orally at 11 to 22 milligrams per kilogram of feed for 4 weeks, beginning at 24 weeks of age, the egg production increased significantly in 2 of 3 years, as compared to that of females reared to 28 weeks old under natural light. Other hormones, including progesterone, testosterone and cortisone, gave variable results. Reserpine in feed at a level of 0.5 mg per kilogram of feed for 3 weeks, beginning at 25 weeks of age, did not overcome refractoriness, although 1.0 and 2.0 mg/kg fed for 3 weeks increased egg numbers, as compared to natural light-control females.

Temperature

Turkey females held under a constant 14-hour 70°F environment were delayed in reaching sexual maturity, and exposure to a 90°F temperature and a 14-hour light-day delayed sexual maturity even more. Females on a constant 8-hour light-day at 70° or 90°F did not reach sexual maturity. When the females were shifted from the 8-hour light-day to a 14-hour day, egg production started in 3 weeks, while under reciprocal treatment females ceased egg production in 1 week.

When turkey females were in a controlled environment with a temperature of 65° (± 5°F) from December to August, or an environment fluctuating with outside temperatures ranging from 23° to 94°F, the rate of egg production was significantly higher for the fluctuating environment. The controlled environment induced broodiness to a greater extent than did the uncontrolled environment. Egg size was depressed in the uniform-temperature-treated female groups, but egg shell thickness (as determined by specific gravity) was not affected.

Altitude

The effect of selection of turkeys for reproductive traits at 7200-and 9100-foot elevations was observed in experiments over a 5-year period. In 4 of the 5 years, average egg production was slightly higher for the lower altitude line. The average egg production per female for the 5 years was 42.7 eggs for the 7200-foot line, and 40.4 eggs for the 9100-foot line.

Body Size

The effect of selection for body weight on reproduction in turkeys was studied in two 7-year experiments. In one experiment, the BBB lines were selected on the following bases: (1) heaviest weight at 8 weeks and 24 weeks, respectively; (2) an index ([8-week weight × 5] minus 24-week weight) selection; and (3) random selection. A significant difference was found in date of first egg between the 8-week weight line and other lines, but the data showed no variation in egg production in all lines that could be attributed to selection. Large turkeys laid eggs of larger size.

In the other 7-year experiment, three single-trait lines of BBB turkeys were selected for large 24-week weight, high egg production, and high hatchability; a random line acted as a concurrent control. While body weight and hatchability increased within each of these selected lines, egg production did not shift in the egg-production-selection-line. At the end of the selection period, reciprocal matings between the egg production and random control lines showed neither maternal effects nor sex-linkage effects on egg production.

Egg-laying Rhythm

The egg production pattern for BBB and BSW (Beltsville Small White) turkeys was observed from February through June, using morning artificial light starting at 7:00 a.m. with extended natural light increasing seasonally. The over-all average time of egg laying appeared to be 1:45 p.m. Time intervals between ovipositions were shortened with increasing clutch (series of

eggs) length, with a lower limit of approximately 25 hours. The time of first oviposition can be used as a criterion for identifying intensive layers. Variations in number and length of clutches show definite dependence upon season. The egg weight was found to decrease for successive eggs within clutches.

FERTILITY

Sexual Maturity

Variability of age at sexual maturity as determined by the first measurable semen sample ranged from 132 to 291 days in BBB males. Differences in date of hatch of 2 weeks or more changed age at maturity from 0 to 50 or more days. Age at maturity differed for strains, and the differences could be increased by selection. At the end of 5-years of selection, early- and late-maturing lines matured at 173 and 218 days, respectively. Heritability of age at maturity was 0.65, based on dam components, and 0.85 for sire variance components. Crosses of early- and late-maturity lines resulted in progeny intermediate in age at maturity, and little differences were found in reciprocal crosses.

Semen Characteristics

Volume. Semen volume produced by BBB males was influenced by age, season, or environment. The mean volume from February to May in each of 2 years averaged 0.235 and 0.266 ml per sample in one strain. Males from lines selected over several generations for early maturity produced an average of 0.300 ml per collection from March through May, as compared to 0.200 ml for late- maturing males. Progeny of the various crosses produced semen intermediate in volume from the volumes of the males of the two lines. Studies on the effect of frequency of collection showed that volume was not decreased by every-other-day collection (as compared to weekly collections). Daily collections decreased semen volume significantly, while 2- or 4-week-apart collections were lower in volume than were weekly collections. Sperm concentrations were not affected by frequency of collection. Heritability of semen volume ranged from 0.20 to 0.40. For spring-hatched BBB males, the correlation between semen volume produced to the end of April, May, and June, was 0.90, 0.95, and 0.98, respectively. Sampling to the end of May gave an adequate estimate of semen volume production during the summer months.

Semen storage, When semen from BSW males was held for 4 hours at 15°C in February prior to artificial insemination (A.I.) the subsequent fertility was equal to 0, 1 and 2 hours of holding time. In April and May marked decline in fertility occurred in all semen, except when it was used immediately after collection (0 holding time).

Fertility Factors

Preconditioning males. Preconditioning males at 50°F increased the level of fertility by 0 to 10 per cent, depending upon the external environmental conditions to which the males were later exposed. In colder climates preconditioning may be of value in the management of turkey males. Sperm production was shown to be depressed by late spring and summer temperatures.

Crossing strains. Crossing seven strains of BBB turkeys for 4 years increased mean fertility in natural mating to 56.4 per cent, while eggs of pure strains were 48.7 per cent fertile. A decrease in fertility was noted in BBB turkeys whose inbreeding coefficients reached 50 to 75 per cent.

Selection for high and low fertility lines. Reciprocal matings involving two lines selected for high and low fertility of females showed that initial fertility and persistency of sperm functional capacity or duration were governed more by the male's genetic background than by that of the

females. Fertility of line-cross progeny was intermediate for both measures on high and low lines. High-fertility line males produced an average of 0.327 ml of semen volume, as compared with 0.183 ml for low-fertility line males. In each of 7 years of selection, volume of high-fertility line males exceeded the volume produced by low line males. Neither body weight and conformation traits of males, nor egg production of females of selected lines, were correlated with semen volume.

Natural mating. Turkeys selected for increased weight at 8 and 24 weeks of age had decreased fertility in natural matings, as compared to random and index-selected lines ([weight at 8 weeks × 5] minus weight at 24 weeks). In natural matings, receptivity of the turkey female was found to decrease rapidly with the season. Although artificial insemination partially offset the decline, it was not the complete answer to the problem.

Shifting males during breeding season. Fertility was not improved in the latter part of the breeding season by the use of a second shift of males. Males for the second shift were maintained on either 0.75 ft-c or 5.0 ft-c of daily light for 8 hours until 6 weeks prior to shifting, at which time both groups received a 14-hour light day with 5 ft-c of light intensity. Light treatments had no effect on fertility. The use of a second shift of males hatched in July did not improve late season fertility in matings where first shift males were hatched in April.

Selection for libido. Selection experiments with BBB turkeys show that there is a wide variability in libido of both sexes and that the trait is inherited. Observation of mating behavior for 30-minutes daily during a 20-day period showed that females were receptive from 0 to 17 times and that matings were completed from 0 to 11 times. Close agreement in mating behavior of male turkeys in natural matings and with an artificial model having a female turkey head indicated that the latter can be used as a method for selecting males for aggressiveness. Semen volumes of high-libido lines were greater than those of low-libido lines. There was conflicting evidence as to correlated response of selection for libido and body size. The data indicate that selection for increased libido, while improving fertility, may lead to a decrease in egg number.

Semen collection. The fertility of turkey eggs was increased significantly when females were artificially inseminated with semen collected in an open glass jigger, as compared to semen collected in a vacuum or aspirator bottle. In another experiment, aeration of turkey semen for 15, 60, or 120 minutes following collection did not affect its fertilizing capacity. Increases in the length of holding time of semen decreased fertility of the turkey eggs.

GROWTH

Breeding Systems

Body weight of strain crosses at market age was 7.5 per cent greater for females and 12.2 per cent greater for males than that of pure strain offspring. Feed efficiency was improved on the order of 2 to 3 per cent for strain crosses, and strain crosses were more uniform in body weight and other conformation measurements.

When four lines (random, growth, egg production, and hatchability) were single- and four-way crossed, maternal effects influenced 8- and 24-week body weights, but sex-linkage was not a factor in body weight and egg production.

Inbreeding had little effect on bone growth, but seemed to substantially decrease muscular development. The worst effects from inbreeding were on growth, viability, and hatchability; the greatest improvement by hybridization has been on these characteristics.

There was considerable variation in 24-

week body weights from inbred-line matings, but there was no increase in body weights of the progeny over that of the parent lines. Body weights were higher for pure lines.

Selection

Selection for early gain in body weight to 8 weeks resulted in increased 24-week and mature weights. A selection index designed to provide early weight gains and improve feed efficiency, while holding breeding age body weights lower, was found effective in experiments with BBB turkeys.

Female turkeys of low-libido line were 2 pounds heavier than females of a high-libido line; whether this difference in body weight can be attributed to lessened mating activity is a matter of conjecture.

There was little difference in body weight at 35 weeks between high- or a low-fertility lines. A line selected for growth showed decreased body weight when eggs were stored longer than 1 week before setting, and there was a slight loss in post-hatching body weight when eggs were lighted during incubation.

Stress applied to eggs during incubation (6 hours of exposure to 32°F) produced poults which were heavier than controls at 8 weeks of age; this difference was no longer evident at 24 weeks of age.

High heritability estimates were found for 24-week body weight, and 8-week body weights were highly correlated with 24-week body weights. Weight at 24 weeks was positively correlated with breast depth, keel length, and (probably) shank length.

Correlation

Experiments on correlated responses from selection showed that turkeys selected over seven generations for large body size at 24 weeks continued to lose fertility and hatchability. Selection for egg production or hatchability resulted in indirect selection for reduced body size.

Consistent decline in fertility and hatchability in a line selected for large body size at 24 weeks, and a decrease in body size in a line selected for high hatchability, may indicate why there is a continuing problem of low hatchability in commercial turkey flocks bred for large market size.

HATCHABILITY

The hatchability problem is an important one to the turkey breeder and to the industry in general. Field observations indicate that temperature, storage time, and shipping factors—which are all involved in handling the egg prior to incubation—influence the ability of eggs to hatch. Research indicates that these factors sometimes augment each other to the detriment of the fertile egg by reducing the number of viable germs present when the egg is in early stages of incubation. But it has been shown that preincubation warming increases the viability of turkey eggs so that more poults can be obtained. It is probable that this additional warming causes the "retarded" blastoderm in eggs of certain hens to move closer to the normal stages usually reached by the time most eggs are laid. The ovulatory cycle (hence, the time an egg remains in the oviduct) probably is a major factor in variation, but inherent viability (growth capacity) of the germ may also be a contributing factor. Hatchability is affected by the genetics of the hen involved and by the breeding system utilized. Incubation conditions influence the ability of the embryo to hatch, and therefore are directly related to egg viability.

Breeding Systems

Because hatchability is inherited, it may be quickly improved by selection. This improvement may be obtained in a number of different ways. Studies involving a comparison of pure lines of BBB turkeys and their reciprocal inter-strain crosses over a 10-year period consistently showed

that strain-cross vigor improved reproductive performance. Hatchability of fertile eggs appeared to be the greatest net gain from strain crossing, although reproductive performance benefitted through a favorable influence on egg production and fertility. Strain crosses exceeded non-inbred pure strains in hatchability by as much as 10 to 20 per cent; crossing inbred lines which had a coefficients of inbreeding of 75 to 80 per cent increased hatchability of their hybrid embryos. Three- and four-way crosses showed a slight but consistent advantage in reproductive performance over two-way crosses.

Pure strains consistently exhibited 2 to 4 per cent higher incidence of embryonic death than did strain crosses—the better reproductive performance of the latter was in part due to fewer dead embryos up to 24 days of incubation. Crosses of pure strains did not provide hybrid vigor in reproductive traits, and testing for combined ability of strains should be a prerequisite to an extension of this practice. There appears to be a genetic co-variation of egg production with hatchability. Selection for increased body weight at 24 weeks has shown a negative relationship to egg production and hatchability.

Natural selection can be used to improve hatchability in BBB turkeys. Stress selection was employed at 24 days of incubation when eggs were transferred to pedigree hatching baskets and placed in a 70°F temperature-controlled cabinet for 5 hours. After this treatment the stress group was returned to the hatching compartment for the remainder of the 28.5 day period of incubation. The general effect of stress incubation was to increase hatchability of fertile eggs by 9 to 16 per cent after one generation of treatment. All genotypes did not respond equally to the treatment, and stress repeated in subsequent generations gave diminished rates of response. First generation treatments were statistically significant as evaluated by second generation response, and genotype effects were significant in both first and second generations after treatment. The high relation of genotype response to treatment during the generations tested indicates that continued stress selection may increase the genetic value for improving hatchability. The basis for this type of work suggests that sufficient stress eliminates genetically weak embryos (thus accelerating natural selection) but not the more vigorous organisms.

Selecting by the use of a chilling technique involving exposure to 32°F for 6 hours on the eighth day of incubation resulted in improved viability of the embryo by the third generation, after two generations of selection. Application of this technique to lines established for their ability to reproduce has demonstrated an increased hatchability of those embryos surviving the treatment. Selecting lines by utilizing the chilling technique, as well as conventional procedures of selection based on ability to reproduce progeny, demonstrates that a parallel selection program can be used.

To evaluate the heritability of hatchability, forty BBB turkey sires were mated to a number of dams. The eggs were stored up to 3 weeks and through seven hatches. Results indicate that holding hatching eggs would not increase the efficiency of selection for hatchability or hatching time. A negative correlation between hatching time and holding time shows that the eggs of poor-hatching hens will hatch later than eggs from high-hatching hens. The natural selection against large turkeys is intensified when hatching eggs are stored. Sex linkage did not appear to have a large degree of influence on hatchability or hatching time.

Egg Storage

The hatchability of eggs stored decreases on the order of 1 to 2 per cent daily for 18 to 14 days, as compared to a negligible per cent for 1 to 7 days storage. Heritability estimates for storage hatchability range from 0.28 to 0.45 and 0.42 to 0.64, respectively, based on the dam component.

The environmental condition of eggs prior to incubation influences hatching results. For example, holding eggs at a temperature of 53°F overnight, preheating at 99.75°F for 5 hours followed by storage at 53°F resulted in a constant improvement in hatchability. Storage temperature appears to be an important factor involved

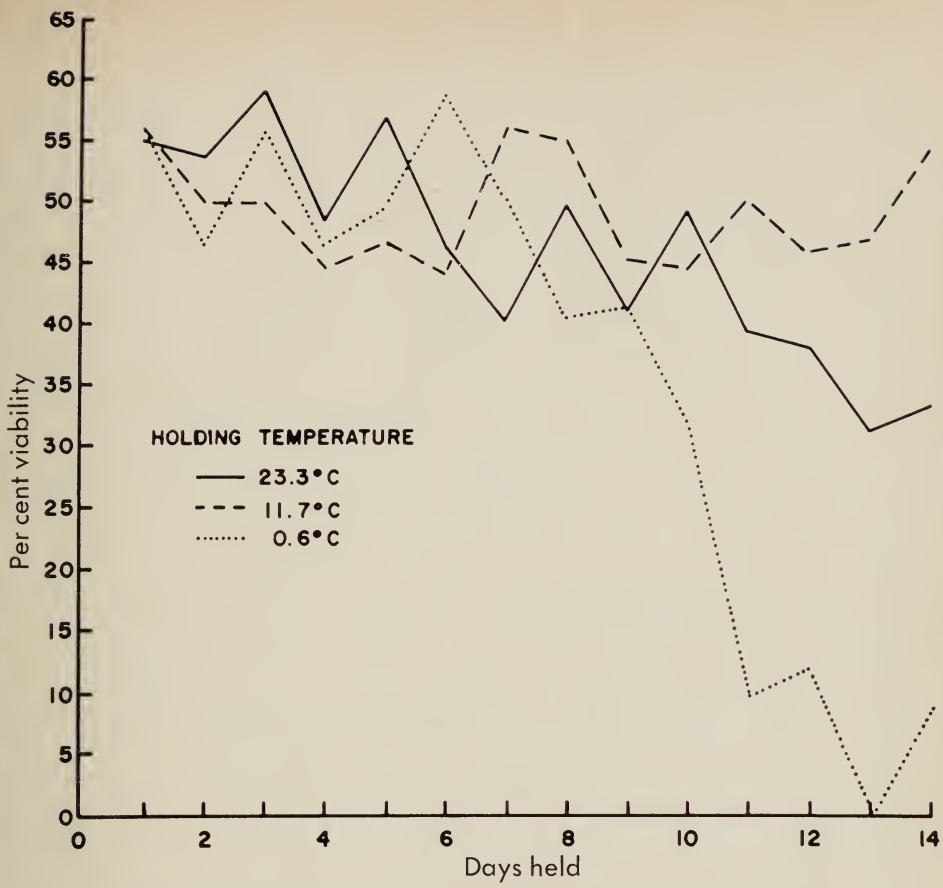

Fig. 1. Viability of BBB eggs held at three different storage temperatures.

when eggs are held beyond 8 days. Figure 1 shows embryo viability over a 14-day holding period without pre-incubation, utilizing three different temperatures with BBB turkey eggs. There was a rather sharp drop in live germs after 6 days of storage at 33°F (0.6°C) while eggs stored at 74°F (23.3°C) began to lose viability after 10 days; eggs held at 53°F (11.7°C) continued at a relatively high level of viability throughout the 14-day period. Extension of this study to a 28-day holding period merely accentuates the differences and reveals a steady drop in viability of eggs stored at 53°F after 14 days. Hatchability of the surviving embryos (fig. 2) indicates a similar pattern of response to the ability to emerge from the egg, with a rather sharp decline when eggs were held at 33° and 74°F. However, eggs held at 53°F, while also declining somewhat, maintained a higher level of hatchability than that of the other two temperature groups.

Pre-incubation warming should be studied further. Studies on strain response as well as duration of germ viability revealed substantial differences in response to this treatment due to genetic background. In the study illustrated by figure 3, pre-incubation warming was carried out on the day the eggs were produced, and eggs were subjected to an environment of 80° to 82°F for a period of 14 hours; then they were stored at 53°F for periods up to 27 days. The data obtained show the beneficial effects of preheating on both BBB and BBW (Broad Breasted Whites). The data also show that preheating was effective beyond the sixteenth day of storage, and that BBB turkeys reacted more mark-

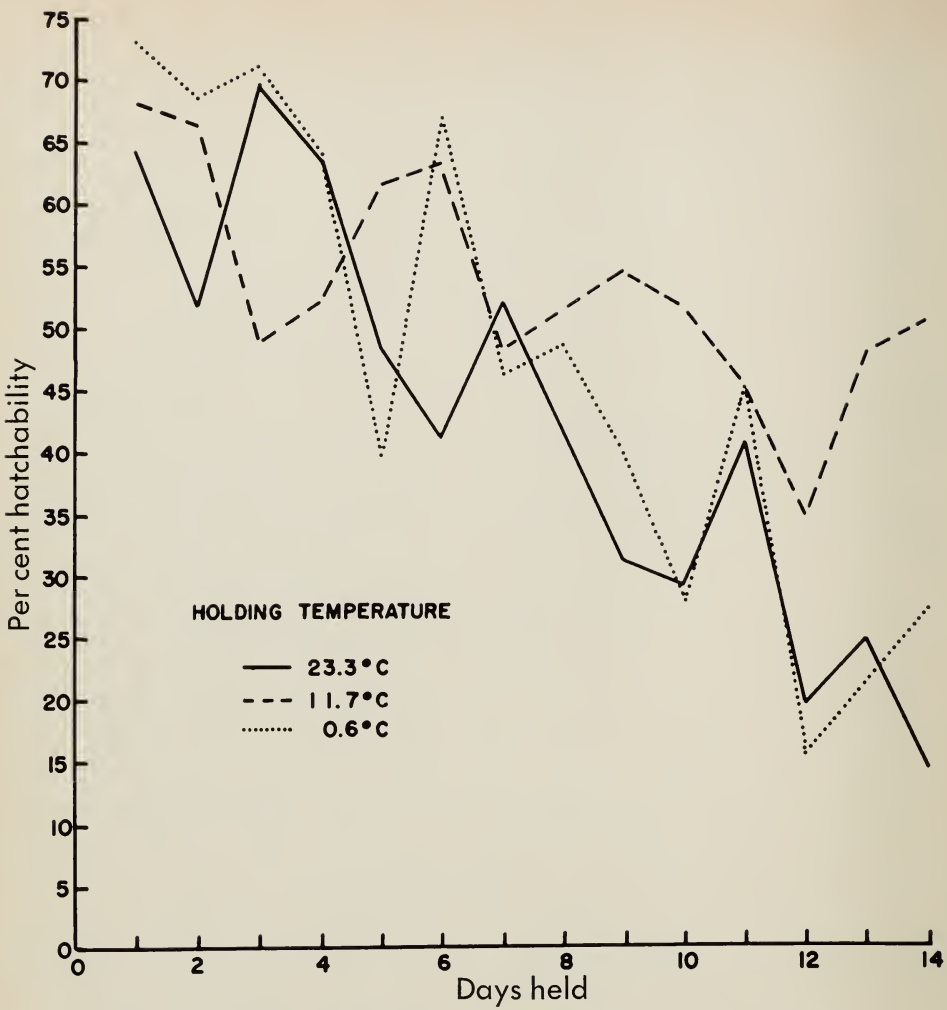

Fig. 2. Hatchability of BBB eggs held at three different storage temperatures.

edly to the treatment than did the BBW turkeys. It is possible that the real reason for response to preheating may be the differences in the development of blastoderms when the egg is laid, and this could be due to various genetic or physiologic factors.

Oxygen Supplementation

To determine the effect of oxygen and pressure on hatchability, two major approaches were followed: genetic selection, and oxygen addition to the incubator. The information obtained has no doubt now been modified as a result of commercial application, as little further work has been carried out to supplement original findings which recommend the maintenance of a 23 to 24 per cent oxygen level in the incubator. Carbon dioxide content should not exceed 0.8 per cent (with a preferred optimum level of 0.6 per cent) but too much ventilation may reduce carbon dioxide to an undersirably low level, with perhaps detrimental effects.

In a study designed to determine the effect of oxygen pressure on selection for hatchability, incubation partial-pressure of 14 per cent of the barometric pressure resulted in a reduction of hatchability of 40

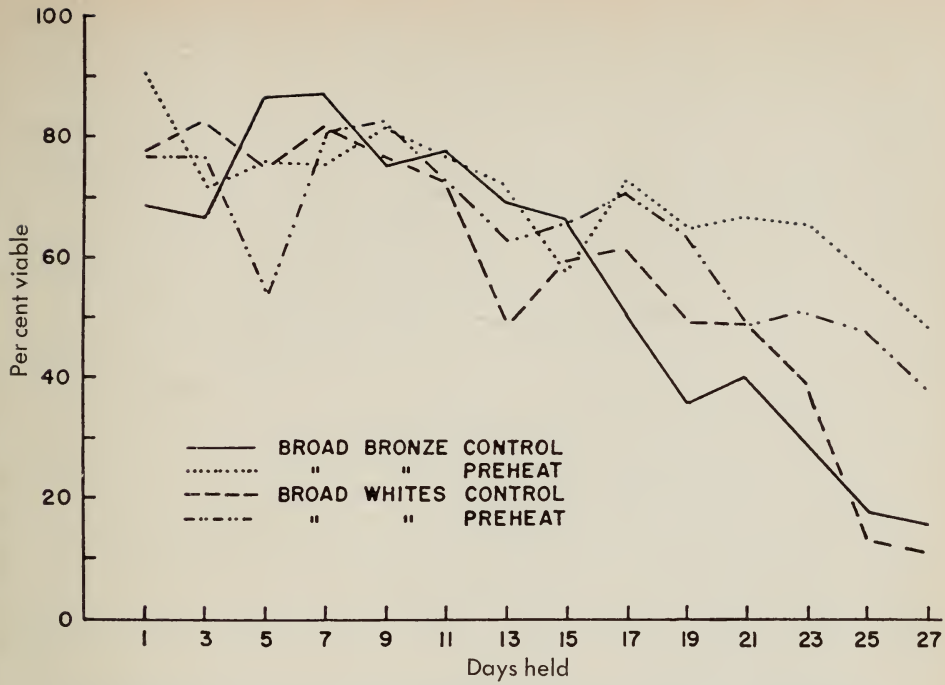

Fig. 3. Strain response to preheating hatching eggs prior to storage, as measured by germ viability on a basis of 2-day increments for 27 days.

per cent when compared with a partial-pressure of 16 per cent of the barometric pressure in control incubators. No statistical interaction was found between hatchability and oxygen pressure; this suggests that natural selection at lower oxygen pressure might be used as a stress factor to improve the hatchability through genetic selection.

Altitude

Further experiments utilizing stress to improve hatchability have shown that hereditary differences in lines may be obtained by selection at different altitudes. Eggs from a line selected for hatchability at 9,100 feet elevation had better hatchability when incubated at that altitude than did eggs from a line produced at 7,200 feet. Similar results were obtained with eggs from hens reared at 7,200 feet compared to eggs of hens reared at 4,300 feet when the eggs were incubated at the 7,200 feet hatchery. Turkey eggs from the same sources declined in hatchability with increasing altitude when the study was carried out in incubators located at 250 to 7,200 feet.

BIBLIOGRAPHY

Publications from W-7 Regional Project

Popular Articles

1947–1957

Asmundson, V. S.

1951. New cooperative breeding research results are good. Turkey World, 26(6):26.

1954. Growers reap benefits of breeders' progress. Turkey World 29(10):17.

Carson, J. D.
1956*a*. Crossing strains and varieties may be next big step in turkey breeding. Turkey World **31**(1):19.
1956*b*. Cross breeding next in turkey breeding. Farm and Home Science, Utah.

Harper, J. A.
1951. Managing turkey breeding flocks. Norbest Turkey News, Jan. 1951 (also in Nulaid News **30**(7):12–14, December 1951).
1953. Selecting the turkey breeders. Norbest Turkey News **18**(2):1, 3–4.
1955*a*. Fertility—simple or complex. Turkey World **30**(2):16.
1955*b*. Selection and management of turkey breeding flocks. The Eggsaminer **32**: 4–5, 25.
1955*c*. You can get hatching eggs the year around. Turkey World **30**(7):17.

Kosin, I. L.
1951. Breeder toms need special care. Washcoegg (Nov.).
1952. How to handle hatching eggs. Washcoegg (Nov.).
1953. Importance of light in turkey breeding. Washcoegg (Nov.).
1954*a*. A look at turkeys 20 years from now. Turkey World **29**(9):14.
1954*b*. On-the-farm tests can be useful. Turkey World **29**(7):15 (July).
1955*a*. When is the best time to select your breeders? Turkey World **30**(7):44.
1955*b*. Turkeys are efficient feed converters. Washcoegg, Vol. 33 (October).
1956*a*. Keep fertility at a peak. Turkey World **31**(10):13.
1956*b*. Select turkey breeding flock with care. Washcoegg. 34:10.
1957*a*. Pre-warming of eggs as a method of improving hatchability. Everybody's Poultry Journal **62**(3):17.
1957*b*. Handle hatching eggs with care. Washcoegg 34:12.

Lorenz, F. W. and J. D. Carson
1951*a*. Where and when should you use artificial insemination? Turkey World **26**(12): 26–27, 105–08.
1951*b*. Artificial breeding of turkeys. California Agriculture 5(12):4, 11.

Lorenz, F. W. and J. J. MacIlraith
1952. Supplementary artificial insemination for turkeys. California Turkey News. pp. 41, 43, 45.

Miller, J. P. and D. D. Jackson
1951. Preheating toms improves fertility and hatchability. Turkey World **26**(12):32, 100–02.

Moreng, R. E.
1957. Colorado's Turkey Research Program. American Poultry Journal **88**:18 (March, 1957).

Publications from W-7 Regional Project
Popular Articles
1958–1964

Becker, W. A.
1962. Handle turkey eggs with care. Western Farmer **40**:36.

Carson, J. D.
1961. Heritability of disease resistance in turkeys. Farm and Home Sci., Utah Agr. Expt. Sta., Logan.

Harper, J. A.
1958. Research takes some mystery out of breeding problems. Turkey World 33(9):14.
1959. It pays to care for hatching eggs. Turkey World 34(11):14.
1960*a*. Fertility in turkeys. American Poultry Journal—Turkey Producer **91**(3):8.
1960*b*. What we know about lighting hens. Turkey World 35(11):16.

Kosin, I. L.
1958*a*. Turkey research contributions. American Poultry Journal—Turkey Producer **89**(10):16.
1958*b*. How soon will we be controlling climate for breeder flocks? Turkey World 33 (4):20.
1959*a*. Use less lighting for poultry? Washcoegg, June 13.
1959*b*. Correlative responses. Hatchery and Feed **70**(7).

Moreng, R. E.
1964. The W-7 Committee—How it helps the industry. Turkey World, 39(3):12.

Publications from W-7 Regional Project
Journal Articles
1947–1957

Abplanalp, H. and I. L. Kosin
1951. Heritability of growth in turkeys. Records Genetics Society of America **20**:89 (Abstract).
1952. Heritability of body measurements in turkeys. Poultry Sci. **31**:781–91.
1953. Genetic variation of fertility and hatchability in the Broad Breasted Bronze turkey. Poultry Sci **32**:321–31.

Asmundson, V. S., and C. F. Pun
1954*a*. Inheritance of rate of growth in Bronze turkeys. Poultry Sci. **33**:411–16.
1954*b*. Growth of Bronze turkeys. Poultry Sci. **33**:981–86.

Burrows, W. T. and I. L. Kosin
1953. The effect of ambient temperature on production and fertilizing capacity of turkey spermatozoa. Physiol. Zool. **26**:131–46.

Buss, E. G.
1955. Observations on the development of inbred turkeys. Poultry Sci. **34**:1185 (Abstract).

Carson, J. D., F. W. Lorenz, and V. S. Asmundson
1953. Semen production of spring hatched Broad Breasted Bronze turkey males. Poultry Sci. **32**:891 (Abstract).
1955*a*. Semen production in the turkey male. I. Seasonal variation. Poultry Sci. **34**:336–43.
1955*b*. Semen production in the turkey male. II. Age at sexual maturity. Poultry Sci. **34**:344–47.
1955*c*. Semen production in the turkey male. III. Quantities produced. Poultry Sci. **34**:348–55.

Harper, J. A.
1949. The rate of response of turkey hens to artificial light as related to production. Poultry Sci. **28**:312–14.
1950. Changes in body weight and conformation of Broad Breasted Bronze turkeys during the breeding season. Poultry Sci. **29**:98–103.
1955. The effect of holding time of turkey semen on fertilizing capacity. Poultry Sci. **34**:1289–91.

Harper, J. A. and W. E. Babcock
1953. The effect of penicillin on early mortality and growth in poults. Poultry Sci. 32:179–80.

Harper, J. A. and J. E. Parker
1950*a*. The relation of breast width and body weight to reproduction in turkey hens. Poultry Sci. 29:305–06.
1950*b*. Family differences in fertility of turkey hens. Poultry Sci. 29:471–73.
1952. Overlapping of progeny resulting from changing males in turkey mating. Poultry Sci. 31:659–64.
1957. Changes in seasonal egg production of turkeys induced through controlled light exposure and force molting. Poultry Sci. 36:967–73.

Herring, Jack W.
1952. Strain variation among Broad Breasted Bronze turkeys. M. S. Thesis, Utah State Agr. College, Logan.

Hunter, Clyde
1951. Strain comparisons among Broad Breasted Bronze turkeys. M. S. Thesis, Utah State Agr. College, Logan.

Johnson, A. S. and V. S. Asmundson
1957. Genetic and environmental factors affecting size of body parts of turkeys.
a. The heritability and interrelationships of body weight and live body measurements. Poultry Sci. 36:296–301.
b. The relation of body weight and certain body measurements to pectoral and tibial muscle weights. Poultry Sci. 36:959–66.
c. The relation of gonad size to body weight and body measurements at three different ages. Poultry Sci. 36:1052–57.
d. Interactions between sire-family and hatch. Poultry Sci. 36:1057–62.

Kosin, I. L.
1948. Parthenogenesis and abortive embryonic development in the domestic fowl. Proc. 8th World's Poultry Congress: 345–51.
1949. Moribund and dead blastoderms—factors in the hatchability complex of turkey eggs. Poultry Sci. 28:771 (Abstract).
1950. Some aspects of early embryonic mortality in domestic fowl. Northwest Sci. 24: 31 (Abstract).
1950*a*. A relationship between the length of storage and incubation periods in Broad Breasted Bronze eggs. Poultry Sci. 29:620–21.
1950*b*. Morphology of moribund blastoderms in turkey eggs. Poultry Sci. 29:767 (Abstract).
1951. A study of the morphology of moribund turkey blastoderms. Proc. 9th World's Poultry Congress 3:75–87
1953. Genetic variability of feathering in turkeys. Poultry Sci. 32:909–10 (Abstract).
1954. Length of preincubation storage and heredity as factors affecting the hatchability of turkey eggs. Poultry Sci., 33:24–28.
1956. Studies on preincubation warming of chicken and turkey eggs. Poultry Sci. 35:1384–92.
1957*a*. A genetic analysis of egg shape in chickens and turkeys. Poultry Sci. 36:1134.
1957*b*. Genetic variability of feathering and growth in domestic turkeys. Records of Genetics Soc. Amer. No. 25:382.

Kosin, I. L. and Hans Abplanalp
1951. The pattern of egg laying in turkeys. Poultry Sci. 30:168–79.

Kosin, I. L., and Jeanne P. Hurley
1957. Variability in the development of avian embryos *in-situ* and *in-vitro*. Transplantation Bul. 4:76–78.

Kosin, I. L., and M. S. Mitchell
1953. Further data on the effect of ambient temperatures on fertility in turkeys. Poultry Sci. 32:910 (Abstract).
1955*a*. Ambient temperature as a factor in turkey reproduction. I. The effect of preheating males and females on their subsequent breeding pen performance. Poultry Sci. 34:484–96.
1955*b*. Ambient temperature as a factor in turkey reproduction. II. The effect of artificially lowered air temperature on the breeding activity of males in late spring and summer. Poultry Sci. 34:499–505.

Kosin, I. L., M. S. Mitchell, and W. J. Burrows
1952. Influence of temperature on the reproductive performance of the Broad Breasted Bronze toms. Poultry Sci. 31:180–82.

Kosin, I. L., and Helen Nagra
1956. Frequency of abortive parthenogenesis in domestic turkey. Proc. Soc. Exper. Biol. & Med. 93:605–08.

Kosin, I. L., E. St. Pierre, and R. McLaughlin
1951. The prevalence of early embryonic mortality in the Broad Breasted Bronze turkeys. Poultry Sci. 30:805–14.

Kosin, I. L. and W. J. Wakely
1950. Persistency of the functional capacity of breed-heterologous turkey semen. Poultry Sci. 29:258–63.

Kosin, I. L., and Anne Wheeler
1956. Methods for estimating spermatozoal numbers in turkey semen. Northwest Sci. 30:41–47.

Law, G. R. J., and I. L. Kosin
1957. The effects of season and two ambient temperatures on the reproductive ability of male turkeys. Poultry Sci. 36:1135.

Lorenz, F. W.
1948. Observations on the onset and duration of fertility in turkeys. Poultry Sci. 27:672 (Abstract).
1950. Deposition of P^{32} in cock spermatozoa. Poultry Sci. 29:769 (Abstract).

Lorenz, F. W., N. E. Wilson, and V. S. Asmundson
1955. Relation of frequency of collection to amount of semen obtained from turkey males. Poultry Sci. 34:634–39.
1956. Effect of long intervals between collection on semen production of turkey males. Poultry Sci. 35:823–25.

Lorenz, F. W., V. S. Asmundson and N. E. Wilson
1956. Turkey hybrids (Meleagris ocellata x Meleagris gallopavo). J. Heredity 47: 142–46.

Mitchell, M. S., and I. L. Kosin
1954. The effect of controlled ambient temperature on some factors associated with egg laying in turkeys. Poultry Sci. 33:186–91.

Moreng, R. E. and P. A. Thornton
1957. Inbreeding and hybridization of turkeys. Poultry Sci. 35:1143 (Abstract).

Parker, J. E. and J. A. Harper
1954. Questions and answers on artificial insemination. Cir. of Inf. 543, O.S.C.

Sato, I., and I. L. Kosin
1960. A cytological study of the parthenogenetically developing turkey germ discs and embryos. Cytologia 25:256–66.

Wakely, W. J., and I. L. Kosin
1951. A study of the morphology of the turkey spermatozoa with special reference to the seasonal prevalence of abnormal types. American J. of Vet. Research 12: 240–45.

Publications from W-7 Regional Project
Journal Articles
1958–1965

Abplanalp, H., F. X. Ogasawara, and V. S. Asmundson

1962. Influence of selection for body weight at different ages on growth of turkeys. Br. Poultry Sci. 4(1):71–82.

Asmundson, V. S.

1958*a*. Western Regional Turkey Breeding Project. Poultry Sci. **37**:1181–82 (Abstract).

1958*b*. Changes in reproduction of turkeys with selection for large size. Proc. 11th Pacific Coast Chicken and Turkey Breeders' Roundtable. University of Calif., Davis.

1959. Relaxed selection in turkeys. Proc. 12th Pacific Chicken and Turkey Breeders' Roundtable. Wash. State Univ., Pullman.

Asmundson, V. S. and U. K. Abbott

1960. Dominant sex-linked slow feathering in the turkey. Poultry Sci. **39**:1231 (Abstract).

1961. Dominant sex-linked late feathering in the turkey. J. Heredity **52**:99–104.

Becker, W. A.

1963. Length of pre-incubation storage of turkey eggs and its effect on body weight. Poultry Sci. **42**(6):1356–59.

Becker, W. A. and T. P. Bogyo

1963. Heritability of developmental time and viability of turkey embryos in three environments. Proc. 12th Intern. Congr. Genetics Vol. **1**:153–54.

Bogyo, T. P. and W. A. Becker

1963. Exact confidence intervals for genetic heritability estimated from paternal half-sib correlations. Biometrics **19**:495–496.

Carson, J. D.

1959. Field testing in turkeys. Proc. 12th Pacific Coast Chicken and Turkey Breeders' Roundtable. Wash. State Univ., Pullman.

1964. Natural selection as a genetic tool for improving hatchability in turkeys. Poultry Sci. **43**:87–94.

Harper, J. A.

1959. Fertility in turkeys. Proc. 12th Pacific Coast Chicken and Turkey Breeders' Roundtable. Wash. State Univ., Pullman.

1963. Development and perforation of the occluding plate in oviducts of young turkey females as related to laying of the first egg. Poultry Sci. **42**:482–85.

1964. Hereditary muscular dystrophy in the domestic turkey, *Meleagris gallopavo*. Poultry Sci. **43**:1326–27

1965. Fertility of turkey eggs as related to method of collecting and aeration of semen. Poultry Sci. **44**:726–31.

Harper, J. A., P. E. Bernier, and W. E. Babcock

1964. Skin melanization of the domestic turkey *Meleagris gallopavo*. Poultry Sci. **43**: 577–83.

Harper, J. A. ,and J. E. Parker

1960. Effect of restricted light and hormones on subsequent egg production of winter hatched turkeys. Poultry Sci. **39**:900–03.

1961. Effect of fall hatch date and length of light restriction on the photoperiodic response of turkey females. Poultry Sci. **40**:1413 (Abstract).

1962. Effect of fall hatch date and length of light restriction on the photoperiodic response of turkey females. Poultry Sci. **41**:493–97.

1965. Effect of light and drugs in controlling egg production of turkeys. Poultry Sci. **44**:778–84.

Ishizaki, H., and I. L. Kosin
1960. Sex chromatin in early chick embryos. Cell Res. 21:197–259.

Kosin, I. L.
1958*a*. Time-lag in identification of fertility in Broad Breasted Bronze eggs and its relation to hatchability and, possibly, parthenogenesis. Poultry Sci. 37:1150–53.
1958*b*. Metabolism of turkey semen as affected by the environment of donor birds. Poultry Sci. 37:376–88.
1958*c*. Environment vs. heredity in improving reproductivity in turkeys. Proc. 11th Pacific Coast Chicken and Turkey Breeders' Roundtable. Univ. of Calif., Davis.

Kosin, I. L., and W. A. Becker
1959. Shifts in the phenotypes of lines within a turkey strain, following several generations of single-trait selective breeding. Poultry Sci. 38:1220 (Abstract).

Kosin, I. L., and H. Ishizaki
1959. Incidence of sex chromatin in *Gallus domesticus*. Science 130:613–14.

Kosin, I. L., and A. M. Mun
1960. Clutch size, oviposition time, and "floor" eggs as factors in turkey hatchability. Poultry Sci. 39:82–89.

Law, G. R. J., and I. L. Kosin
1958*a*. The rate of temperature change in turkey eggs subjected to short-term incubation and subsequent cooling. Poultry Sci. 37:316–21.
1958*b*. Seasonal reproductive ability of male domestic turkeys as observed under two ambient temperatures. Poultry Sci. 37:1034–47.

Law, G. R. J., W. J. Miller, and V. S. Asmundson
1960. Blood types of turkeys. Poultry Sci. 39:1268 (Abstract).

Lorenz, F. W., U. K. Abbott, V. S. Asmundson, H. E. Adler, F. H. Kratzer, F. X. Ogasawara, and J. D. Carson
1959. Turkey Fertility. Circ. 472, Calif. Agr. Expt. Sta.

Marsden, S. J., N. S. Cowen, and L. M. Lucas
1962. Effect of gradual and abrupt lengthening of photoperiod on reproductive response of turkeys. Poultry Sci. 41:1864–68.

Marsden, S. J., and M. Lucas
1964. Effect of short day or low intensity light treatment on reproduction of fall hatched turkeys in two environments. Poultry Sci. 43:434–41.

Moreng, R. E., and T. E. Hartung
1958. Turkey Breeding Practices Guide. Colo. Agr. Expt. Sta. Bul. 502–S.
1959. Turkey Breeding Practices. Colo. Agr. Expt. Sta. Bul. 502–S.

Moreng, R. E. and M. L. Jones
1961. Chilling and embryonic development of turkey eggs. Poultry Sci. 40:1433 (Abstract).

Moreng, R. E., and P. A. Thornton
1958. Hybridization through inbreeding and strain crossing of turkeys. Proc. 11th World's Poultry Congress, Mexico.

Mun, A. M., and I. L. Kosin
1958. The early turkey embryo on media prepared from eggs of "high" and "low" hatchability hens. Growth 22:9–15.

Mun, A. M., I. L. Kosin and I. Sato
1959. The effect of spleens from different animals on the growth of the chick embryo spleen. Anat. Record 134:613–614 (Abstract).

Ogasawara, F. X., V. S. Asmundson and W. O. Wilson
1959. The effect of restricting light during the adolescent period on reproductive performance in turkeys subsequently exposed to a 12- and 14-hour day. Poultry Sci. 38:1233 (Abstract).

Ogasawara, F. X., W. O. Wilson and V. S. Asmundson
1962. The effect of restricting light during the adolescent period on reproductive performance in turkeys subsequently exposed to a 12- 14- and 20- hour day. Poultry Sci. **41**:1858–63.

Ogasawara, F. X., H. Abplanalp and V. S. Asmundson
1963. Effect of selection for body weight on reproduction in turkey hens. Poultry Sci. **42**:838–42.

Sato, I., and I. L. Kosin
1958. Chromosome complements in parthenogenetic turkey embryos. Proc. 10th Intern. Congr. Genetics Vol. **2**:249–50 (Abstract).

Suzuki, N., and I. L. Kosin
1962. The age of RBC donors and the immunological differences in genetically isolated lines of domestic turkeys. Genetics **47**:(8)989–90 (Abstract).

Wilson, W. O., F. X. Ogasawara and V. S. Asmundson
1962. Artificial control of egg production in turkeys by photoperiods. Poultry Sci. **41**: 1168–75.

Wolfe, H. R., W. J. Miller and V. S. Asmundson
1961. Antibody production in pheasant-turkey hybrids. Poultry Sci. **40**:140–44.

7½*m*-4,'67 (G9079) VL